Faculty of Engineering

SWMM MODELING OF WATER SENSITIVE URBAN DESIGN: DRY DETENTION POND FOR RESIDENTIAL ESTATE

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SWMM MODELING OF WATER SENSITIVE URBAN DESIGN:

DRY DETENTION POND FOR RESIDENTIAL ESTATE

AFDAL HAZIQ MOHAMMAD SALEHE

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ABSTRACT

Dry ponds which are also called detention ponds are stormwater basins that are designed to intercept volume of stormwater runoff and temporarily impound the water for gradual release to the receiving stream or waterways. This thesis is to analyze the application of dry pond as a Water Sensitive Urban Design in Taman Casa Marbella, Tabuan Laru, Sarawak, Malaysia using Storm Water Management Model (SWMM). SWMM is used to estimate runoff in storm water drainage components. Three different scenarios are developed, which are first, directly uncontrolled runoff, secondly dry pond, and thirdly dry pond with underground detention storage. The modeling output has determined that the peak discharge of using detention pond is 48% lower than the uncontrolled or direct discharge. Furthermore, 0.9m deep underground storage is expected to fully detend runoff from 10-years ARI storm. But with MSMA recommendations, 0.6m deep dry pond with 0.4m underground storage is found to be the most suitable design.

ABSTRAK

Kolam takungan yang juga dikenali sebagai kolam tadahan air yang direka bentuk untuk menakung air dan melepaskannya secara beransur-ansur ke dalam parit ata sistem pembentung. Tesis ini adalah untuk menganalisa penggunaan kolam tadahan air di Taman Casa Marbella, Tabuan Jaya Sarawak, Malaysia menggunakan Storm Water Management Model (SWMM). SWMM digunakan untuk menganggarkan kuantiti aliran air. Tiga senario yang berlainan iaitu yang pertama, aliran secara terus, yang kedua, aliran dengan kolam tadahan air, dan yang ketiga, aliran dengan kolam tadahan serta kolam simpanan air. Hasilnya, kajian ini telah menentukan bahawa kadar aliran tertinggi bagi kolam takungan adalah 48% lebih rendah daripada aliran secara terus. Tambahan pula, kedalaman 0.9m simpanan bawah tanah dijangka menakung sepenuhnya aliran untuk 10 tahun ARI. Tetapi berdasarkan cadangan MSMA, 0.6m kedalaman bagi kolam kering dengan simpanan bawah tanah 0.4m adalah reka bentuk yang paling sesuai.

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CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is the seventh highest growth rate of development country in Southeast Asia after Laos (CIA 2012). Rapid growth has changed the topography of the country as more lands are opened for development. Construction of infrastructures to meet the needs of the people such as roads, buildings, airports and shopping complexes have resulted in lower permeability of the surface terrain, particularly in urban areas to decrease. This affects the existing water cycle in the area and thus, contributes to many problems.

Before the development is undertaken, this land area acts as a rainforest catchment to absorb most of the rain water into ground water table. When the cutting of trees as well as land clearing are done, the storage space of water in the urbanized land decreases with increasing runoff. This increase can cause adverse effects such as flash flooding, erosion and so on, especially in the downstream river.

The three diagrams (Figure 1.1) illustrate how the water-cycle works in natural and urban areas.

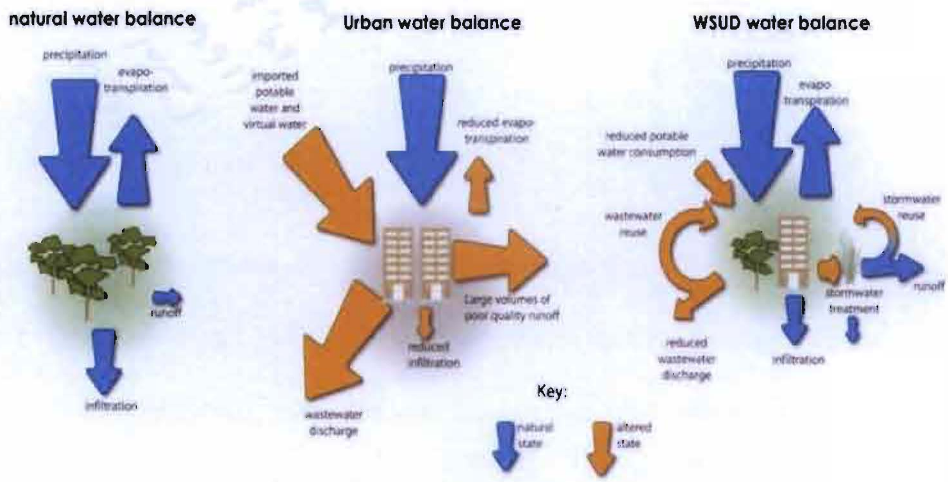

Figure 1.1 Water Cycle in Natural, Urban and WSUD Design area

Management of storm water runoff has caused the formation of two main approaches that differ fundamentally in terms of controlling the amount of storm water runoff. As generally known, the conventional approach that has been practiced in flood control management in our country are fast flow. A prime example of the steps that are done in this approach is like the expansion and deepening of the channel size. This method is found to require a larger area and the high cost of each renovation and upgrading of surface runoff channels do.

With that, this country has gone a step further by practicing a new approach. With emphasis on the preservation and conservation of the environment, the Malaysian Department of Irrigation and Drainage has introduced the Urban Stormwater Management Manual for Malaysia, MSMA in 2000. This approach plays a role by providing slowing off source of runoff and releases it slowly into the drainage system of runoff downstream, adhering to the concepts of Water Sensitive Urban Design (WSUD).

1.2 Problem Statement

One of the components of water cycle is the process of infiltration, where rain water seeps into the soil layers. Such natural process is hindered, in which conventional concrete drains contain the rainwater within its compounded channel walls for rapid disposal. It discontinues the natural infiltration process particularly in urbanized landscape.

In order to re-introduce a healthy urban water cycle, this infiltration process should be incorporated in a storm. However, at present, it is quite difficult to change the existing drainage system, especially in a well-established residential area. Having a WSUD component that can be integrated into a rigid drainage system would be the most welcome to reduce any disturbances to the residents.

As such, a detention system of WSUD approach is attempted here, in the form of a dry pond, to be fitted to an existing concrete drainage system in any typical terrace housing estate. The dry pond is intended as an agent that provides temporary storage of runoff, at the same time, allowing infiltration of rain water side by side a conventional drainage system.

1.3 Aim and Objectives

The aim of this study is to investigate the application of dry pond in residential areas by using Storm Water Management Modeling (SWMM). In order to achieve this aim, two objectives are drawn which are:

i. To develop storm water conveyance model incorporating dry pond in SWMM modeling platform; and
ii. To explore the impact and effectiveness of dry pond in the chosen residential area, Casa Marbella, Tabuan Laru.

1.4 Scope of Study

The scope of the study covers important matters to achieve the aim and objectives of this research. The research focuses on the following matters:

i. Targeted area is typical terrace housing estate in Kuching, Sarawak with large roof surface and concrete drainage system;
ii. Analysis is conducted using EPA SWMM 5.0 software;
iii. Runoff discharge are simulated for a single storm event only; and
iv. Design rainfall of high intensity is adopted by referring to MSMA guideline.

1.5 Organization of Thesis

The structure of the thesis is important in order to get the step by step towards the objectives and the aim of the study. The thesis consists of five main chapters which start with the introduction until the conclusion of the study.

Chapter 1: Introduction

This part exposes and discusses on the background and general information which include the definitions, problem statements, research objectives and scopes. This is to give the readers a primary picture on what is to be discussed on the following sections.

Chapter 2: Literature Review

Secondary data which is gathered from journals, literature and internets are composed together in this chapter to give more understanding about the title as well as the problem statement. This includes further understanding about the dry detention ponds, WSUD and modeling of stormwater drainage. As the first chapter gives the primary picture of the thesis, this chapter acts as the full elaboration of the picture so that the readers understand the concepts, terms, processes and results of the study.

Chapter 3: Research Methodology

This part discusses on the research methodology that is used in this research. Here, the steps of the thesis towards the objectives of the study are discussed.

Chapter 4: Results and Analysis

This chapter presents the results of the simulation using EPA SWMM. The results are interpreted to discuss the effects of dry pond in a housing estate.

Chapter 5: Conclusion and Recommendations

This chapter is the conclusion of the research. From introduction, literature review, methodology, and lastly the results and analysis are concluded based on the objectives and the aim of the study. Some recommendations are projected to assist the future works in the field of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, concepts and ideas related to hydrology regarding on this thesis are discussed to help the readers to understand the whole picture of the project. Water/hydrologic cycle, rainfall-runoff relationship, urban storm water, dry pond and modeling of storm water drainage are the main components of this study. As stated in the first objective, the simulation of this study is carried out using SWMM model. So, the basic concepts and functions of the model are elaborated in this chapter.

2.2 Water/Hydrologic Cycle

As discussed in the problem statement in previous chapter, disturbance of the infiltration process due to development is the main factor that contributes to flash floods in urban area. Because natural infiltration is one main processes of hydrological cycle, understanding on the infiltration process is essential and therefore it is discussed in the following writings.

Patra (2008) defines the hydrologic cycle as the sequence of cyclic events which correlates the movement of water from the atmosphere to the earth's surface and then to the large water bodies through surface and subsurface routes and finally going back to atmosphere. The ocean is the earth's largest reservoir which stores 97 percent of the terrestrial water.

There are six main components of hydrologic cycle which are precipitation, infiltration, evaporation, transpiration, surface runoff, and groundwater flow. When water is evaporated by the sun, it forms into clouds in which later water vapor falls to the land and the sea as precipitation (mostly rains), and continuously finds its way back to the atmosphere through hydrological processes for example evaporation or transpiration. For most cases, evaporation and transpiration are sometimes combined together and called evapotranspiration.

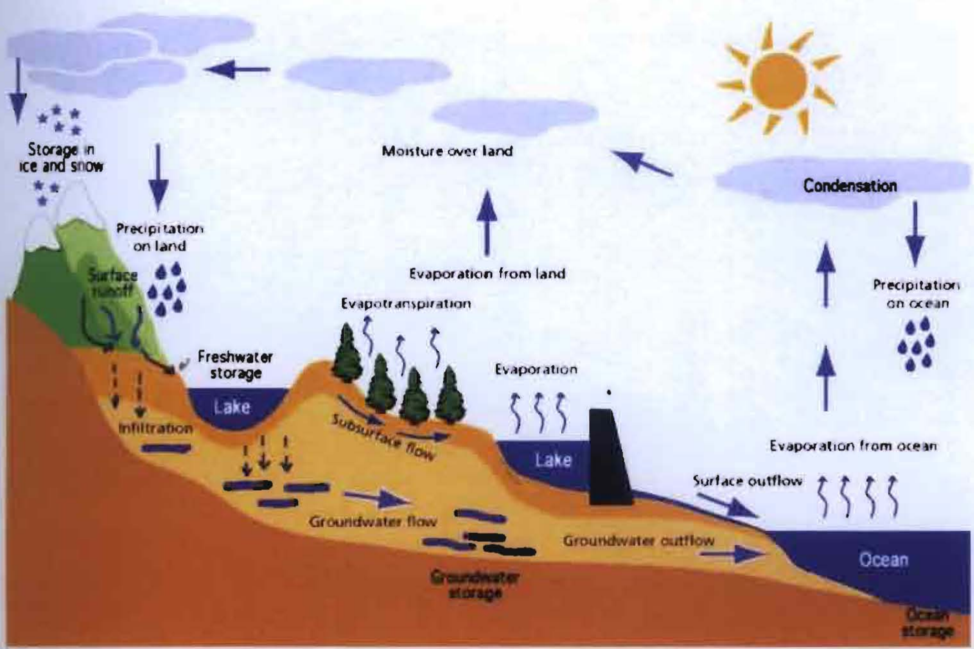

Figure 2.1 Water Cycle

Figure 2.1 shows the process of the hydrologic cycle system. As the water seeps into the land, plants consume up infiltrated water and ground water and return a part of it to the atmosphere through their leaves, and the process is known as transpiration. Some infiltrated water emerges to surface water bodies as interflow, while other portions become groundwater flow. After an initial filling of interception and depression storage, and providing that the rate of precipitation exceeds that of infiltration, overland flow or known as surface runoff begins. The system is a continuous cycle and happening throughout the day (Viessman and Lewis 2003).

2.3 Rainfall-Runoff Relationship

When rain falls, it is intercepted by leaves and stems of vegetation. This is usually referred to as interception storage. When the rainfall continues, water reaching the ground surface infiltrates into the soil until its infiltration capacity is reached.

Thereafter, surface puddles, ditches, drain and other depressions are filled until it is full, then the runoff is generated. The infiltration capacity of the soil depends on its texture and structure, as well as on the antecedent soil moisture content from the previous rainfall or dry season. The initial capacity for example of a dry soil is high but, as the storm continues, it decreases until it reaches a steady value termed as final infiltration rate.

The runoff generation process continues as long as the rainfall intensity exceeds the actual infiltration capacity of the soil but it stops as soon as the rate of rainfall drops below the actual rate of infiltration (Figure 2.2).

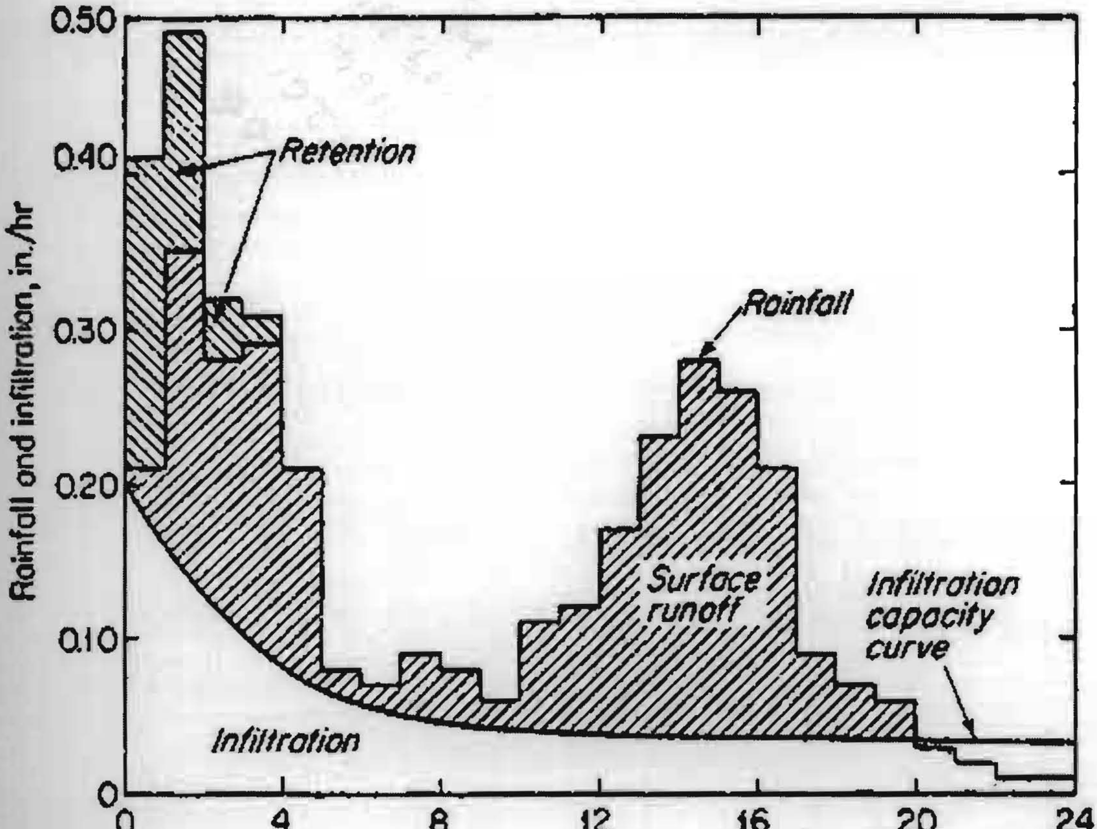

Figure 2.2 Relationships of Rainfall, Infiltration and Runoff in Natural Catchment (Linsley *et al.* 1958)

2.4 Urban Stormwater

Sections 2.2 and 2.3 discuss about the hydrology in a natural catchment. From this section onwards, it deals with urbanized catchment after the intervention of human activities. An urban environment has a different rainfall-runoff relationship compared to natural catchment, mainly due to a drastic change to infiltration, evaporation and transpiration processes in its water cycle. As a result, precipitation is directly converted to surface runoff with increased volumes, while less to groundwater flow.

This alteration of water cycle in urban catchment has caused numerous problems, like flash flood and loss of natural habitats. Because of this, WSUD is an effort to incorporate the natural processes to urban water cycle in hoping to restore as much as possible a balanced water cycle. The Australian National Water Commission (2004) has outlined the WSUD objectives which are to:

i. minimise impacts on existing natural features and ecological processes;
ii. minimise impacts on natural hydrologic behaviour of catchments;
iii. protect water quality of surface and ground waters;
iv. minimise demand on the reticulated water supply system;
v. improve the quality of and minimize polluted water discharges to the natural environment;
vi. incorporate collection treatment and/or reuse of runoff, including roof water and other stormwater;
vii. reduce run-off and peak flows from urban development;
viii. re-use treated effluent and minimize wastewater generation;
ix. increase social amenity in urban areas through multi-purpose green space, landscaping and integrating water into the landscape to enhance visual, social, cultural and ecological values;